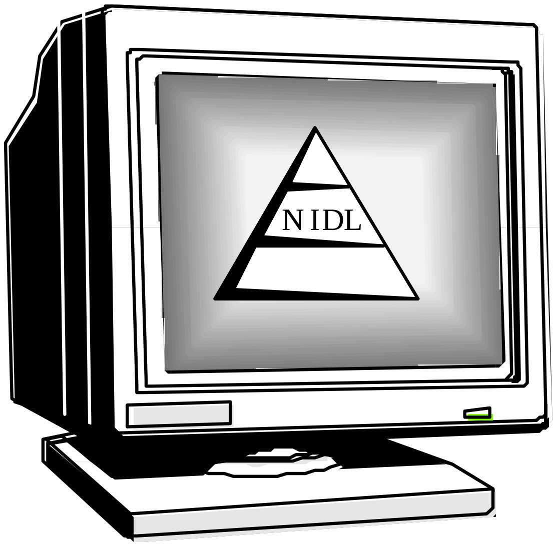

The Orwin Associates DEX 2102L Monochrome CRT Monitor is an excellent 1600 x 1280 pixel, 21 inch monochrome gray scale monitor. The monitor easily passes all the IEC monochrome monitor specifications for both monoscopic and stereo viewing. We have separated the monoscopic from the stereoscopic viewing for grading, but both modes receive an "A" for performance for the Image Analyst and Cartographer applications. This COTS monitor is an excellent display for NIMA Imagery Exploitation Workstations. Accordingly, NIDL certifies the Orwin Associates DEX 2102L Monochrome CRT Monitor as being suitable for IEC workstations requiring a monochrome monitor. The monitor passes all stereo specifications with a Nuvision panel and its associated passive glasses, or with StereoGraphics active glasses. We calculated the dynamic range for various amounts of light falling on the face of the tube for monoscopic operation based on our measurements of reflectivity. We expect the Orwin DEX2102L monitor to have a dynamic range of 398:1 with 3 fc, 158:1 for 10 fc, and 117:1 for 14 fc falling on the screen. The amount of light falling on the screen can be minimized by using a shield to block strong overhead light to thereby increase the contrast ratio.

Evaluation of the Orwin Associates DEX 2102L, 4 x 3 Aspect Ratio, 21-Inch Diagonal Monochrome Monitor (a.k.a. DEX 2101L in NIDL report)

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NIDL IEC Monitor Certification Report

The Orwin Associates DEX 2102L Monochrome CRT Monitor

FINAL GRADES
Monoscopic Mode: A
Stereoscopic Mode: A

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way

The Orwin Associates DEX 2102L (NIDL had previously misstated the model number in its report as the DEX2101L monitor) Monochrome CRT Monitor is an excellent 1600 x 1280 pixel, 21 inch monochrome gray scale monitor. The monitor easily passes all the IEC monochrome monitor specifications for both monoscopic and stereo viewing. We have separated the monoscopic from the stereoscopic viewing for grading, but both modes receive an “A” for performance for the Image Analyst and Cartographer applications. This COTS monitor is an excellent display for NIMA Imagery Exploitation Workstations. Accordingly, NIDL certifies the Orwin Associates DEX 2102L Monochrome CRT Monitor as being suitable for IEC workstations requiring a monochrome monitor. The monitor passes all stereo specifications with a Nuvision panel and its associated passive glasses, or with StereoGraphics wired active glasses. We calculated the dynamic range for various amounts of light falling on the face of the tube for monoscopic operation based on our measurements of reflectivity. Thus, we would expect the Orwin DEX2102L monitor to have a dynamic range of 398:1 with 3 fc, 158:1 for 10 fc, and 117:1 for 14 fc falling on the screen. The amount of light falling on the screen can be minimized by using a shield to block strong overhead light to thereby increase the contrast ratio.

The Orwin Associates DEX 2102L Monochrome CRT Monitor has a very wide possible dynamic range. It easily exceeds the 300:1 dynamic range in monoscopic mode, achieving 147 fL for Lmax and 0.1 fL for Lmin for a dynamic range of over 1000:1. The maximum luminance, Lmax, can be adjusted to lower values i.e. 36 fL in monoscopic mode. We observed 34 fL through the NuVision screen and passive glasses in the stereo mode. The 27:1 extinction ratio far exceeds the requirement in the IEC specification so stereo performance may be better than experienced with some other monochrome or color displays. Active StereoGraphics wired glasses also give a high extinction ratio; we expect the StereoGraphics Zscreen to perform similarly to the NuVision screen. The 4:3 aspect ratio and the 21 inch diagonal give the analyst a large working area surpassed only by 24-inch wide-screen monitors.

The contrast modulation for the Orwin Associates DEX 2102L Monochrome CRT for 1 pixel on/1 pixel off exceeds the IEC requirement by 20% to 50% at 147 fL. The contrast modulation is expected to be even higher at lower luminance settings.

We have viewed other Orwin Associates Monochrome CRT Monitors that have been chosen for use by image analysts at other government sites serviced by Lockheed-Martin Company, Valley Forge, PA. Performance to date has been excellent. A reliability problem found with an excessively tightened crimp has been repaired and the manufacturing procedure modified. The reliability of Orwin Associates DEX 2102L monitor is stated by the manufacturer as 25,000 hours MTBF and as >20,000 hours for the CRT cathode.

The manufacturer states that they have over thirty years experience in high resolution displays for military, aerospace and custom geospatial and related satellite imaging. The full digital control architecture provides repeatable long term performance and automatic calibration of black level. On-screen user controls are standard, and the menu format separates user controls from service areas with password protection. The specific Orwin DEX 2102L monitor NIDL evaluated has a Serial Number 99230001, Part Number 100456-05-75-A, Type MM21E, Manufacture Date 8/18/1999, 120-240V, 2.5A. Orwin states that Clinton Electronics manufactures the CRT.

The performance in room ambient is listed in the attached NIDL evaluation data sheet. Light incident on the face of the monitor is reflected to the viewer in the amount governed by the reflectivity of the face of the CRT for monoscopic operation, and by the reflectivity of the LCD stereo panel for stereo operation. We calculated the dynamic range for various amounts of light falling on the face of the tube for monoscopic operation based on our measurements of reflectivity. Thus, we would expect the Orwin DEX2102L monitor to have a dynamic range of 398:1 with 3 fc, 158:1 for 10 fc, and 117:1 for 14 fc falling on the screen. The amount of light falling on the screen can be minimized by using a shield to block strong overhead light and thereby increase the contrast ratio.

NIDL has evaluated an alternative COTS monochrome monitor from PIC/Siemens. The 1600 x 1200 pixel, landscape Orwin DEX2102L monitor has performance very similar to the PIC21si/Siemens model number 21103L (Stereo) monitor. The Orwin 1988 landscape monitor with the NIDL-designed electron gun in native 1408 x 1408 pixel format is like the Orwin 1974D vertically scanning replacement for the specially-manufactured original IDEX monitor. Its contrast modulation at 1 pixel on/1 pixel off exceeds either the PIC21si or the Orwin DEX2102L at the 120-170 fL luminance levels, while other performance values are similar to the PIC or DEX2102L. Thus, all three monochrome monitors pass the IEC minimum specifications. The choice may be made on price for the IEC workstation or on preferred features.

The Clinton/Orwin website is http://www.cec-displays.com/index2.htm.
The StereoGraphics stereo shutter web site is at http://www.stereographics.com/.
The NuVision LCD stereo shutter web site is at http://www.nuvision3d.com/

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1600 x 1200	pass
Dynamic Range	25.4 dB	30.6 dB	pass
Luminance (Lmin)	0.1 fL min. ± 4%	0.1 fL	
Luminance (Lmax)	35 fL ± 4%	147 fL	pass
Uniformity (Lmax)	28% max.	17.0%	pass
Halation	3.5% max.	1.0%	pass
Color Temp	Not specified	9627 K	
Reflectance	Not specified	8.2%	
Bit Depth	8-bit± 5 counts	8-bit	pass
Step Response	No visible ringing	Clean	pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 Δ u'v'	0.0037 delta u'v'	pass
Pixel aspect ratio	Square H = V± 6%	Set to square	pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.2 ins.	pass
Cm, Zone A, 7.6 inch dia.	35% min.	46%	pass
Cm, Zone A, 40% area	35% min.	44%	pass
Cm, Zone B	20% min.	33%	pass
Pixel density	72 ppi min.	105 ppi	pass
Straightness	0.5% max ± 0.05 mm	0.38%	pass
Linearity	1.0% max ± 0.05 mm	0.83%	pass
Jitter	2 ± 2 mils max.	1.54 mils	pass
Swim, Drift	5 ± 2 mils max.	1.84 mils	pass
Warmup time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	27 mins.	pass
Warmup time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	56 mins.	pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute minimum	Set to 77 Hz	pass
STEREOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 2048 (I)	pass
Lmin	0.1 fL min. ± 4%	0.09 fL	
Lmax	30 fL min ± 4%	34.1 fL	pass
Dynamic range	24.77 dB min	25.8 dB	pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 Δ u'v'	0.010 delta u'v'	pass
Refresh rate	60 Hz per eye, min	60 Hz, per eye	pass
Extinction Ratio	20:1 min	27:1 (n)	pass
AMBIENT LIGHTING			
Dynamic Range 26 dB (398:1)	N/A	3 fc	
Dynamic Range 22 dB (158:1)	N/A	10 fc	
Dynamic Range 20.7 dB (117:1)	N/A	14 fc	

* denotes Moiré cancellation turned ON
(I) denotes interlaced scanning
(n) denotes Nuvision LCD shutter panel

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The NIDL is hosted by the Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics.

The present study evaluates a production unit of the Orwin Associates DEX 2102L , monochrome CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091*, *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC)*, August 25, 1999.

Two companion documents that describe how the measurements are made, are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*

- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*
  Publication No. 0201099-091, Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC), August 25, 1999.

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1 The Orwin Associates DEX 2102L Monochrome CRT Monitor

Manufacturer's Specifications

The specifications for the Orwin Associates DEX 2102L supplied by Orwin Associates are listed in Table I.1.

Orwin Associates, Inc. has over thirty years experience in high resolution displays for military, aerospace and custom geospatial and related satellite imaging. The full digital control architecture provides repeatable long term performance and automatic calibration of black level. On-screen user controls are standard on the DEX Series and the menu format separates user controls from service areas with password protection.

The model DEX2102 L 21" Diagonal in Landscape is a two megapixel high contrast modulation display for NIMA applications up to 1600x1280 pixels. Using the same electron optics as the DEX2105 five megapixel monitor (61% anti-reflective panel and low noise P45 phosphor) calibrated for operation at 30 to 40 fL in controlled ambient conditions, the DEX2102 presents a narrow pixel column and a minimum of 50% contrast modulation. The conservative design provides long term stability and the option to operate at higher luminance levels. Clinton Electronics manufactures the CRT.

TABLE I.1 Revised May 21, 1999

COMPLIANCE LIST HIGH RESOLUTION MONOCHROME MONITOR REQUIREMENTS
DEX2100L 21" LANDSCAPE MONOCHROME MONITOR with BRIGHTNESS STABILIZATION and DIGITAL REMOTE CIRCUITS

PARAMETER	EXPECTED MINIMUM PERFORMANCE	COMPLIANCE	LEVEL OF COMPLIANCE
SIZE	TBD		19.7W x 17.2H x 23.6D
PROTRAIT/LANDSCAPE	LANDSCAPE	YES	
RUGGEDIZED	NOT REQUIRED		INDUSTRIAL RUGGED
REMOTE DIGITAL CONTROLS	RS232 PORT	YES	RS232 Port plus 3 Button OSD
PIXEL ADDRESSABILITY	Up to 2,560 x 2,048	YES	Set to Required
SPOT PITCH	100 dpi	YES	140 dpi, set to required
50% LINE WIDTH WORST	<0.01 INCHES	YES	<.008"
MAXIMUM LUMINANCE	>36 ftL	YES	>100 ftL, set to 36 ftL
MAXIMUM LUMINANCE,Stereo	>80 ftL	YES	>100 ftL, set to 80 ftL
LUMINANCE UNIFORMITY	<20%	YES	<20%
LUMINANCE DYNAMIC RANGE	>360 to 1	YES	>360 to 1
LUMINANCE STABILITY	<3%	YES	Peak <3%
			Background 0.1 +/- .03 ftL
WAVINESS	<0.4%	YES	<0.4%
VERTICAL SCAN RATE	>70 FRAMES/SEC NON-INTERLACED	YES	Set by Dome
STEREO	1K x 1K @ 112 Hz	YES	
WARM UP	<10 MIN to 1%	YES	with calibration
LINEARITY	<1%	YES	<1%
RASTER SIZE STABILITY	<0.1%	YES	<0.1%
JITTER	<0.15 mm	YES	<0.1 mm
FACEPLATE REFLECTIVITY	SPECULAR <20%	YES	<10%
(SPECULAR/DIFFUSE)	DIFFUSE <3%	YES	Not Sure
CONTRAST RATIO	>75 to 1	YES	75 to 1 in 50 LUX Ambient

HALATION	<2%	NO	<5%
CONTRAST MODULATION WORST	>50%	YES	>50%
RESOLVABLE PIXELS (Cm=50%)	>1,600 x 1,280	YES	
MTBF	10,000 HOURS	YES	25,000 Hours
CATHODE LIFE	10,000 HOURS	YES	>20,000 Hours
CALIBRATION	>400 HOURS	YES	>400 Hours
VIDEO BANDWIDTH			>200 MHz
VIDEO RISE TIME (30 Volts)			<2.5 nsec
VIDEO RISE TIME (3 Volts)			<2.0 nsec

** To get a CONTRAST RATIO of 75 in 50 LUX ambient, Orwin can increase their brightness to 66.5 ftL or use a darker panel on the (62%). Present panels are 92% and changing to 62% could impact July 1 deliveries.

I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimetermeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and.Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- Nuvision 19-inch LCD shutter with passive polarized eyeglasses.
- StereoGraphics active glasses and no shutter panel

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black dynamic range measured in 1600 x 1200 format is from 30.6 dB in a dark room. It decreases to under 22 dB (the absolute threshold for IEC) in 10 fc diffuse ambient illumination incident on the screen.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93} . Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are silmutaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene ice box. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Define dynamic range by: $DR=10\log(Lmax/Lmin)$

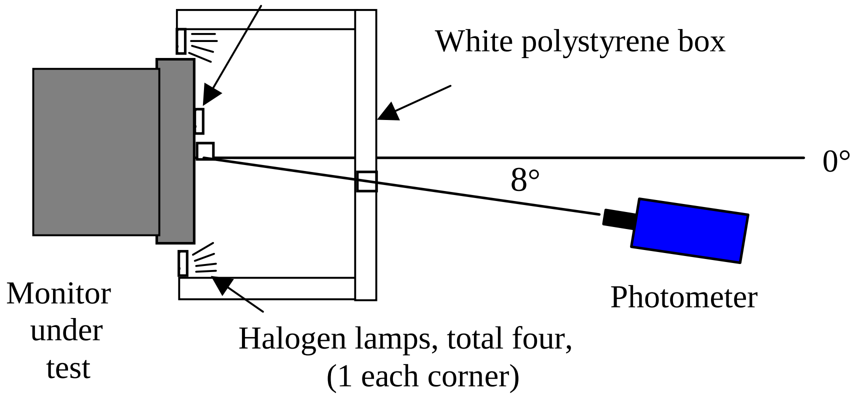


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate
VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	20 fc
Reflected Luminance	1.63 fL
Faceplate Reflectance	8.2 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 30.6 dB in a dark room to 22 dB (the absolute threshold for IEC) in 10 fc diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms
Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = fL.

Ambient Illumination	Displayed Addressable Format 1600 x 1200
0 fc (Dark Room)	30.6 dB
1 fc	28.4 dB
2 fc	27.0 dB
3 fc	26.0 dB
4 fc	25.1 dB
5 fc	24.4 dB
6 fc	23.8 dB
7 fc	23.2 dB
8 fc	22.8 dB
9 fc	22.3 dB
10 fc	21.9 dB
11 fc	21.6 dB
12 fc	21.3 dB
13 fc	21.0 dB
14 fc	20.7 dB
15 fc	20.4 dB

II.2. Maximum Luminance (Lmax)

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.*

The highest luminance for Lmax was 147 fL measured at screen center in 1600 x 1200 format.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1600 x 1200	9627 K	0.262	0.333	147 fL

II.3. Luminance (Lmax) and Color Uniformity

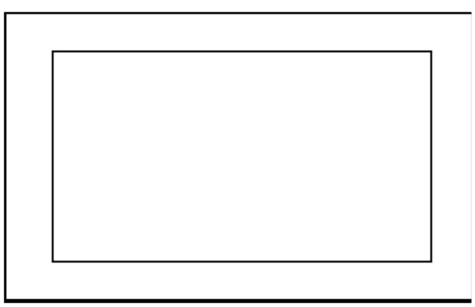
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 17% across the screen. Chromaticity variations were less than 0.004 delta u'v' units.

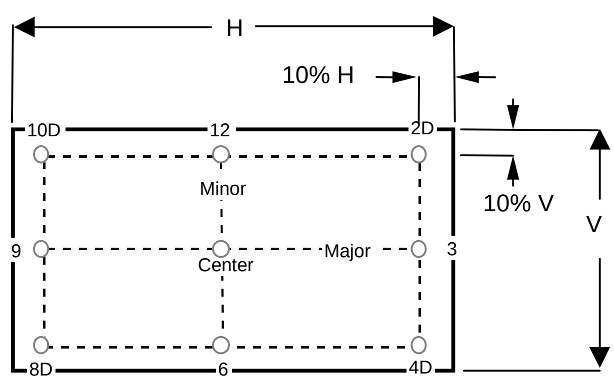
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.
Figure II.3-1



Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of Δ u´v´.

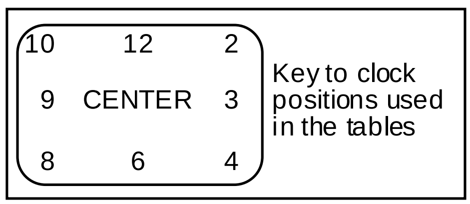
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

1600 x 1200

POSITION	CCT, K	CIE x	CIE y	L, fL
center	9627	0.262	0.333	147
2	10030	0.258	0.330	126
3	9880	0.259	0.332	139
4	9955	0.259	0.330	123
6	9806	0.261	0.330	128
8	9994	0.260	0.327	124
9	9956	0.260	0.328	134
10	10071	0.259	0.327	122
12	9880	0.260	0.330	126



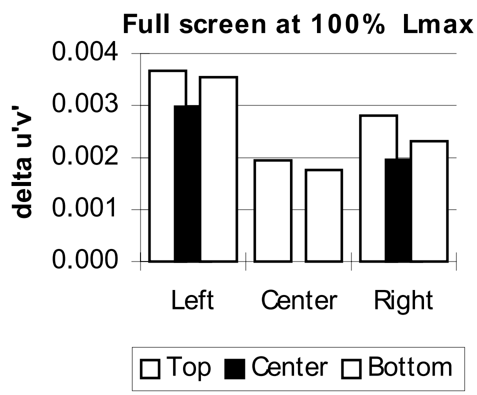


Fig.II.3-3. Spatial Uniformity of Luminance Chromaticity.
(Delta u'v' of 0.004 is just visible.)

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 1.03% +/- 0.09% on a small black patch surrounded by a large full white area.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

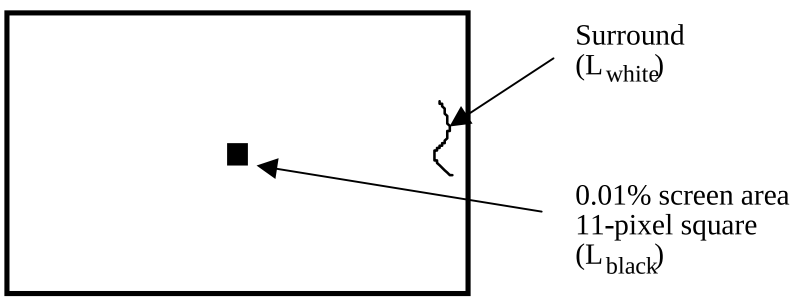


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer which is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation} = L_{black} \;/\; (L_{white} - L_{black}) \times 100$$

Where, L_{black} = measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white} = measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1600 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	1.23 fL ± 4%	1.18 fL to 1.28 fL
Lwhite	119 fL ± 4%	114 fL to 124 fL
Halation	**1.03 % ± 0.09%**	**0.95 % to 1.12 %**

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of the measured white point is 9627 K and is not specified for monochrome monitors for IEC.

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. No black level clipping nor white level saturation were observed.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM model to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM model was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

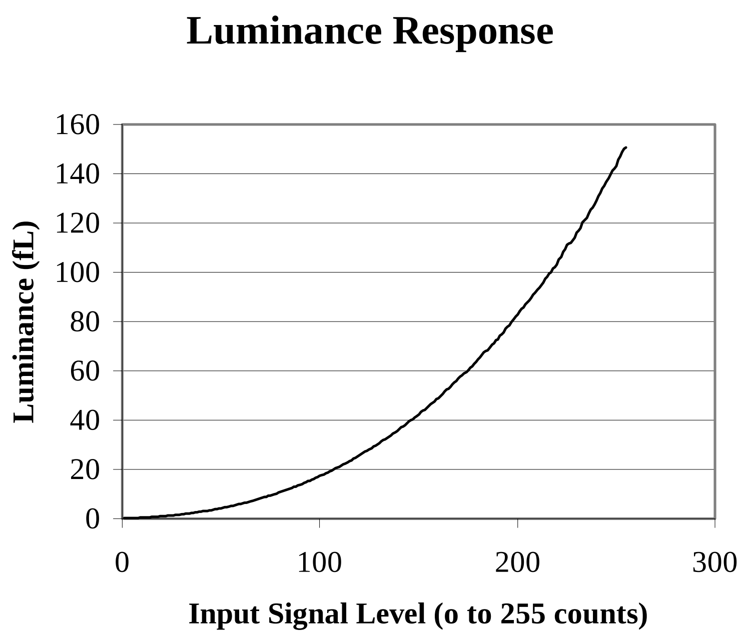


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.166	0	0
39	1	0.187	0.021	4
39	2	0.209	0.022	4
39	3	0.234	0.025	4
40	4	0.26	0.026	4
40	5	0.284	0.024	4
41	6	0.318	0.034	5
41	7	0.35	0.032	4
41	8	0.378	0.028	3
42	9	0.416	0.038	5
42	10	0.458	0.042	4
42	11	0.497	0.039	4
43	12	0.542	0.045	5
43	13	0.588	0.046	4
43	14	0.636	0.048	4
44	15	0.683	0.047	4
44	16	0.738	0.055	5
44	17	0.797	0.059	4
45	18	0.862	0.065	5
45	19	0.922	0.06	4
45	20	0.982	0.06	4
46	21	1.055	0.073	5
46	22	1.118	0.063	3
46	23	1.193	0.075	5
47	24	1.251	0.058	3
47	25	1.329	0.078	4
48	26	1.416	0.087	5
48	27	1.504	0.088	4
48	28	1.586	0.082	4
49	29	1.663	0.077	3
49	30	1.777	0.114	5
49	31	1.869	0.092	4
50	32	1.96	0.091	4
50	33	2.076	0.116	5
50	34	2.156	0.08	3
51	35	2.279	0.123	4
51	36	2.381	0.102	4
51	37	2.497	0.116	4
52	38	2.63	0.133	4
52	39	2.757	0.127	4
52	40	2.847	0.09	3
53	41	2.994	0.147	5
53	42	3.126	0.132	3
53	43	3.225	0.099	3
54	44	3.359	0.134	4
54	45	3.502	0.143	4
55	46	3.651	0.149	4
55	47	3.832	0.181	4
55	48	3.966	0.134	3
56	49	4.138	0.172	5
56	50	4.273	0.135	3
56	51	4.442	0.169	3
57	52	4.565	0.123	3
57	53	4.784	0.219	5
57	54	4.965	0.181	3
58	55	5.093	0.128	3
58	56	5.28	0.187	4
58	57	5.481	0.201	3
59	58	5.659	0.178	4
59	59	5.884	0.225	4
59	60	5.989	0.105	2
60	61	6.228	0.239	4
60	62	6.465	0.237	4
60	63	6.614	0.149	2

Background	Target	L, fL	Diff, fL	Diff, JND
61	64	6.876	0.262	4
61	65	7.022	0.146	3
62	66	7.263	0.241	3
62	67	7.554	0.291	5
62	68	7.81	0.256	3
63	69	8.003	0.193	3
63	70	8.216	0.213	3
63	71	8.47	0.254	3
64	72	8.703	0.233	3
64	73	8.923	0.22	3
64	74	9.242	0.319	4
65	75	9.451	0.209	3
65	76	9.701	0.25	3
65	77	9.862	0.161	2
66	78	10.23	0.368	4
66	79	10.56	0.33	3
66	80	10.79	0.23	3
67	81	11.08	0.29	3
67	82	11.31	0.23	2
67	83	11.64	0.33	4
68	84	11.86	0.22	2
68	85	12.21	0.35	4
69	86	12.52	0.31	3
69	87	12.91	0.39	3
69	88	13.1	0.19	2
70	89	13.49	0.39	4
70	90	13.78	0.29	2
70	91	14.11	0.33	3
71	92	14.49	0.38	3
71	93	14.77	0.28	3
71	94	15.23	0.46	3
72	95	15.44	0.21	2
72	96	15.72	0.28	2
72	97	16.07	0.35	3
73	98	16.64	0.57	4
73	99	16.84	0.2	2
73	100	17.33	0.49	3
74	101	17.69	0.36	3
74	102	17.99	0.3	2
74	103	18.34	0.35	3
75	104	18.78	0.44	3
75	105	19.22	0.44	3
76	106	19.56	0.34	2
76	107	19.95	0.39	2
76	108	20.42	0.47	3
77	109	20.77	0.35	3
77	110	21.07	0.3	1
77	111	21.63	0.56	4
78	112	22.04	0.41	2
78	113	22.4	0.36	2
78	114	22.88	0.48	3
79	115	23.48	0.6	3
79	116	23.76	0.28	2
79	117	24.3	0.54	3
80	118	24.65	0.35	2
80	119	25.26	0.61	3
80	120	25.63	0.37	2
81	121	26.17	0.54	3
81	122	26.72	0.55	2
81	123	27.21	0.49	3
82	124	27.65	0.44	2
82	125	28.15	0.5	2
83	126	28.58	0.43	2
83	127	29.24	0.66	4

Table II.6-2. System Tonal Transfer at center screen as a function of input counts Target levels 128 to 255.

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
83	128	29.68	0.44	2	106	192	74.87	0.65	1
84	129	30.24	0.56	2	106	193	75.65	0.78	2
84	130	30.7	0.46	2	106	194	77.05	1.4	2
84	131	31.35	0.65	3	107	195	77.84	0.79	2
85	132	31.82	0.47	2	107	196	78.37	0.53	1
85	133	32.28	0.46	2	107	197	79.62	1.25	2
85	134	32.67	0.39	1	108	198	81.11	1.49	3
86	135	33.37	0.7	3	108	199	82.1	0.99	1
86	136	33.84	0.47	2	108	200	82.77	0.67	2
86	137	34.47	0.63	3	109	201	84.22	1.45	2
87	138	35.17	0.7	3	109	202	85.08	0.86	2
87	139	35.46	0.29	1	109	203	85.75	0.67	1
87	140	36.28	0.82	3	110	204	87.04	1.29	2
88	141	37.26	0.98	3	110	205	87.74	0.7	1
88	142	37.42	0.16	1	111	206	88.67	0.93	2
88	143	37.91	0.49	2	111	207	89.72	1.05	1
89	144	38.72	0.81	3	111	208	90.83	1.11	2
89	145	39.4	0.68	2	112	209	91.75	0.92	2
90	146	40.07	0.67	2	112	210	92.87	1.12	1
90	147	40.31	0.24	1	112	211	93.72	0.85	2
90	148	41.04	0.73	3	113	212	94.77	1.05	1
91	149	41.66	0.62	2	113	213	95.88	1.11	2
91	150	42.44	0.78	2	113	214	97.34	1.46	2
91	151	43.27	0.83	3	114	215	98.21	0.87	2
92	152	43.78	0.51	2	114	216	99.38	1.17	1
92	153	44.25	0.47	1	114	217	99.88	0.5	1
92	154	44.89	0.64	2	115	218	101.6	1.72	3
93	155	45.71	0.82	3	115	219	102.2	0.6	1
93	156	46.55	0.84	2	115	220	103.1	0.9	1
93	157	47.07	0.52	2	116	221	105.1	2	3
94	158	47.63	0.56	1	116	222	106.2	1.1	1
94	159	48.48	0.85	3	116	223	108.3	2.1	3
94	160	48.92	0.44	1	117	224	109.4	1.1	2
95	161	49.59	0.67	2	117	225	111.23	1.83	2
95	162	50.57	0.98	3	118	226	111.7	0.47	1
95	163	51.63	1.06	3	118	227	112	0.3	0
96	164	52.54	0.91	2	118	228	113	1	1
96	165	52.83	0.29	1	119	229	114	1	2
97	166	53.62	0.79	2	119	230	116	2	2
97	167	54.46	0.84	2	119	231	116.8	0.8	1
97	168	55.25	0.79	2	120	232	118	1.2	2
98	169	55.8	0.55	2	120	233	120.2	2.2	3
98	170	56.83	1.03	2	120	234	121.4	1.2	1
98	171	57.63	0.8	2	121	235	122.1	0.7	1
99	172	58.13	0.5	2	121	236	124	1.9	2
99	173	58.92	0.79	2	121	237	125.4	1.4	2
99	174	59.54	0.62	1	122	238	126.3	0.9	1
100	175	60.25	0.71	2	122	239	127.6	1.3	1
100	176	61.26	1.01	2	122	240	129.2	1.6	2
100	177	61.85	0.59	2	123	241	131	1.8	2
101	178	62.81	0.96	2	123	242	132.1	1.1	2
101	179	63.51	0.7	1	123	243	133.9	1.8	2
101	180	64.56	1.05	3	124	244	135	1.1	1
102	181	65.38	0.82	1	124	245	136.7	1.7	2
102	182	66.6	1.22	3	125	246	138.1	1.4	1
102	183	67.42	0.82	2	125	247	139.7	1.6	2
103	184	68.09	0.67	1	125	248	141.3	1.6	2
103	185	68.38	0.29	1	126	249	142.2	0.9	1
104	186	69.52	1.14	2	126	250	143	0.8	0
104	187	70.64	1.12	3	126	251	145.7	2.7	3
104	188	71.27	0.63	1	127	252	146.9	1.2	1
105	189	72.47	1.2	2	127	253	148.8	1.9	2
105	190	72.73	0.26	1	127	254	150.2	1.4	2
105	191	74.22	1.49	3	128	255	150.6	0.4	0

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

No video artifacts were observed.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern

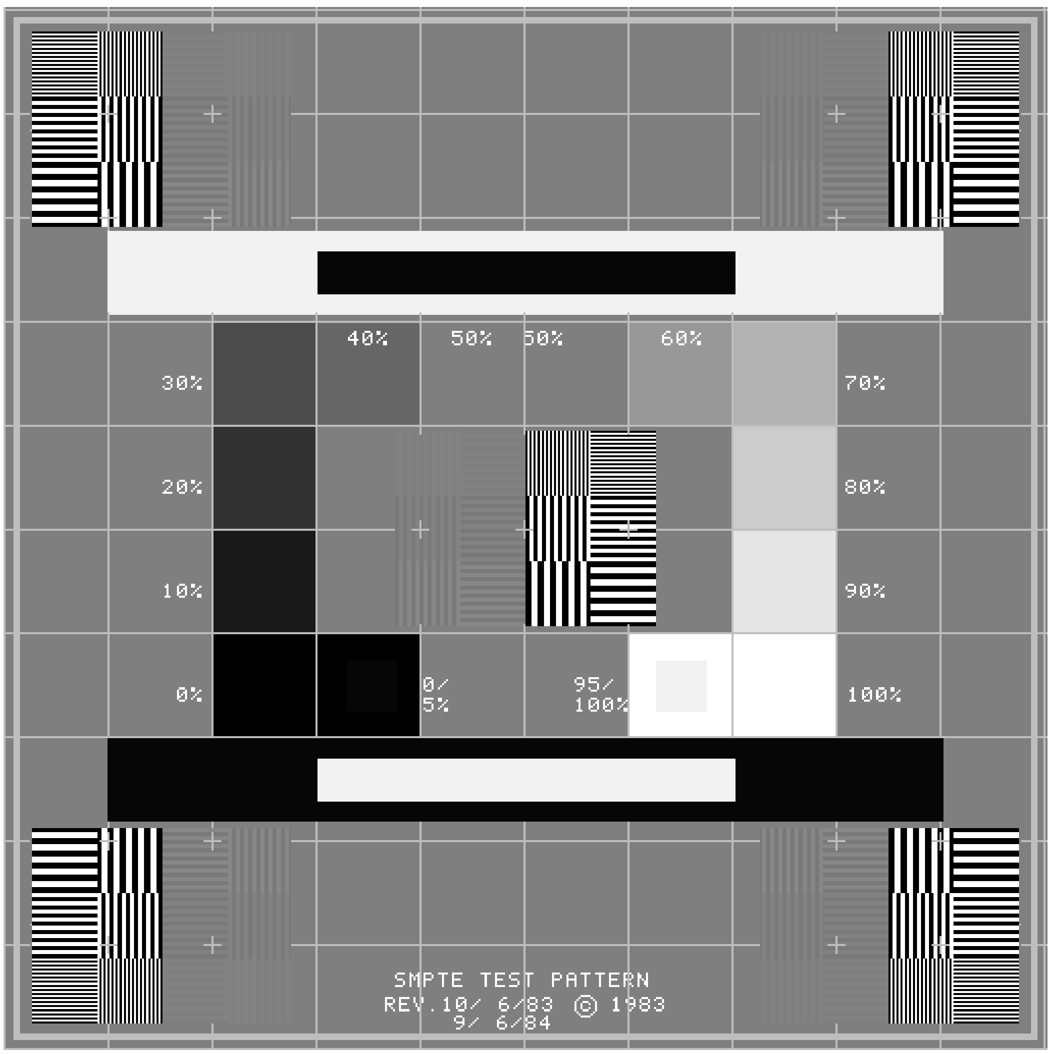


Figure II.8-1. SMPTE Test Pattern .

Data: Define pass by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." None of these artifacts was observed in the ORWIN ASSOCIATES DEX 2102L monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the following tested formats (HxV): 1600 x 1200x 77 Hz, and 1024 x 1024 x 120 Hz.

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals and, for monochrome monitors, no strongly visible moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereo Mode
1600 x 1200	**1024 x 1024**

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is within 0.5%.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

	Monoscopic Mode
Addressability (H x V)	**1600 x 1200**
H x V Image Size (inches)	15.305 x 11.533
H x V Pixel Spacing (mils)	9.57 x 9.61 mils
H x V Pixel Aspect Ratio	**H = V + 0.5%**

II.11. Screen Size (Viewable Active Image)

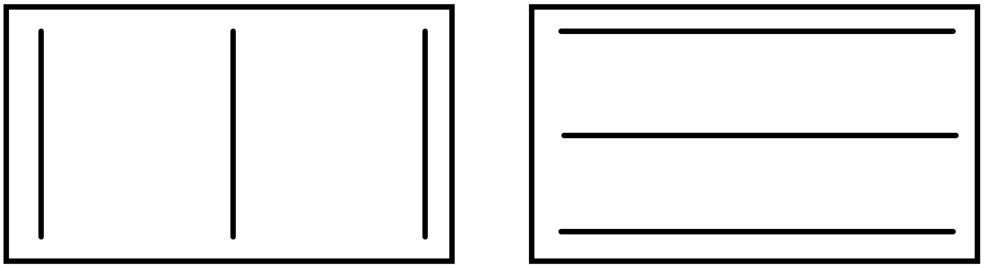
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size as tested was 19.164 inches in diagonal.

Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any overscanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Mode
Addressability (H x V)	**1600 x 1200**
H x V Image Size (inches) Diagonal Image Size (inches)	15.305 x 11.533 **19.164**

II.12. Contrast Modulation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 44% in Zone A, and exceeded Cm = 33% in Zone B.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

Procedure: The maximum video modulation frequency for each 1600 x 1200 format was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax..

Zone A is defined as a 24 degree subtense circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 51% in Zone A, and is equal to or greater than 35% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

Table II.12-1. Contrast Modulation
Corrected for lens flare and Zone Interpolation

Zone A 7.6-inch diameter circle for 24-degree subtense at 18-inch viewing distance

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	71%	42%			80%	53%			84%	36%
			76%	50%	80%	54%	81%	47%		
Major	84%	55%	82%	55%	79%	54%	85%	49%	90%	45%
			76%	54%	81%	55%	81%	46%		
Bottom	72%	53%			82%	55%			83%	33%

Zone A 9.48-inch d**iameter circle for 40% area**

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	71%	42%			80%	53%			84%	36%
			75%	48%	80%	53%	82%	45%		
Major	84%	55%	82%	55%	79%	54%	86%	48%	90%	45%
			76%	54%	81%	55%	81%	44%		
Bottom	72%	53%			82%	55%			83%	33%

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was set to ppi for the 1600 x 1200-line addressable format.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
Addressability (H x V)	**1600 x 1200**
H x V Image Size (inches)	15.305 x 11.533
H x V Pixel Density, ppi	**105 x 104**

II.14. Moire

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

Not applicable to monochrome monitors.

II.15. Straightness

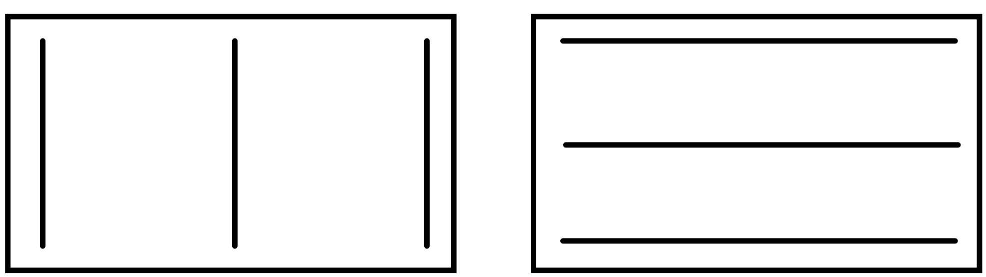
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.38% of the image width or height.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

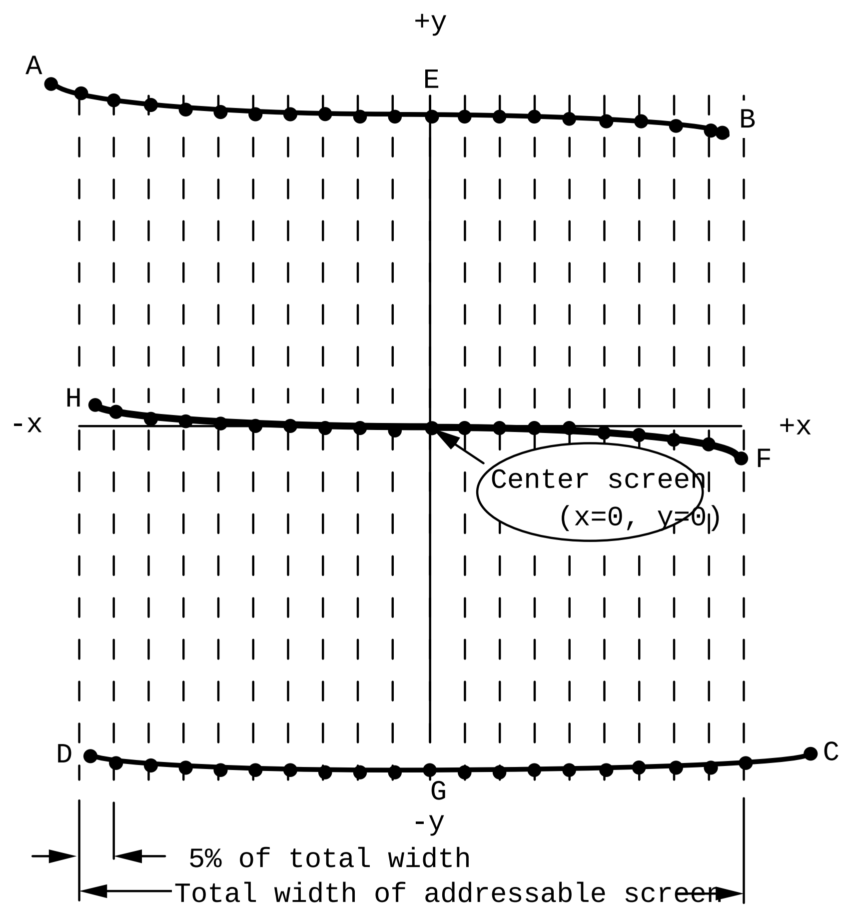


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness
Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-7764	5817	-7770	-5930	-7796	-12	15	5774	-7766	5802	7525	5753
-7200	5817	-7200	-5934	-7200	-12	15	5400	-7780	5400	7540	5400
-6400	5815	-6400	-5929	-6400	-10	10	4800	-7780	4800	7550	4800
-5600	5815	-5600	-5936	-5600	-9	7	4200	-7789	4200	7559	4200
-4800	5813	-4800	-5940	-4800	-9	5	3600	-7786	3600	7565	3600
-4000	5807	-4000	-5944	-4000	-7	3	3000	-7781	3000	7568	3000
-3200	5801	-3200	-5947	-3200	-7	2	2400	-7777	2400	7569	2400
-2400	5794	-2400	-5949	-2400	-6	1	1800	-7773	1800	7568	1800
-1600	5788	-1600	-5950	-1600	-5	0	1200	-7769	1200	7566	1200
-800	5782	-800	-5950	-800	-4	0	600	-7760	600	7563	600
0	5778	0	-5954	0	0	0	0	-7764	0	7561	0
800	5780	800	-5954	800	3	0	-600	-7766	-600	7566	-600
1600	5780	1600	-5962	1600	3	1	-1200	-7769	-1200	7567	-1200
2400	5782	2400	-5972	2400	3	3	-1800	-7773	-1800	7568	-1800
3200	5783	3200	-5981	3200	1	3	-2400	-7776	-2400	7569	-2400
4000	5784	4000	-5987	4000	1	4	-3000	-7780	-3000	7568	-3000
4800	5783	4800	-5992	4800	0	5	-3600	-7783	-3600	7565	-3600
5600	5782	5600	-5993	5600	1	7	-4200	-7784	-4200	7559	-4200
6400	5776	6400	-5989	6400	2	8	-4800	-7782	-4800	7550	-4800
7200	5767	7200	-5982	7200	3	10	-5400	-7777	-5400	7539	-5400
7523	5758	7519	-5977	7542	3	14	-5760	-7772	-5736	7527	-5775

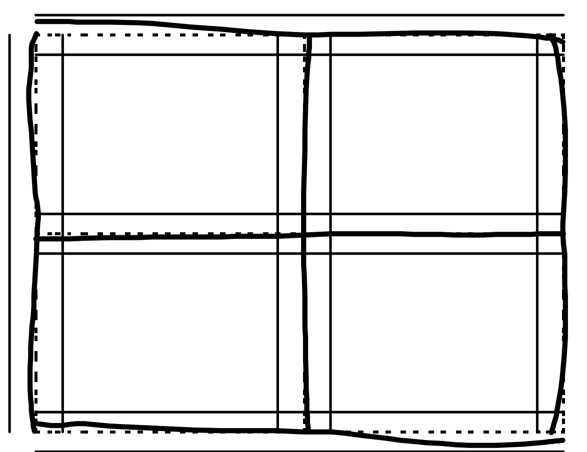


Figure II.15-3 Waviness of Orwin Associates DEX 2102L Monochrome monitor in 1600 x 1200 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for the1600 x 1200 format was set to 77 Hz.
Vertical refresh rate for the 1024 x 1024 stereo format was set to 120 Hz.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	**Stereo Mode**
Addressability	**1600 x 1200**	**1024 x 1024**
Vertical Scan	77 Hz	120 Hz
Horizontal Scan	100 kHz	144 kHz

II.17. Extinction Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio averaged 27 to 1 (29 left, 25 right) at screen center. Luminance of white varied by up to 7.2% across the screen. Chromaticity variations of white were less than 0.010 delta u'v' units.

Objective: Measure stereo extinction ratio

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using a commercially-available Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

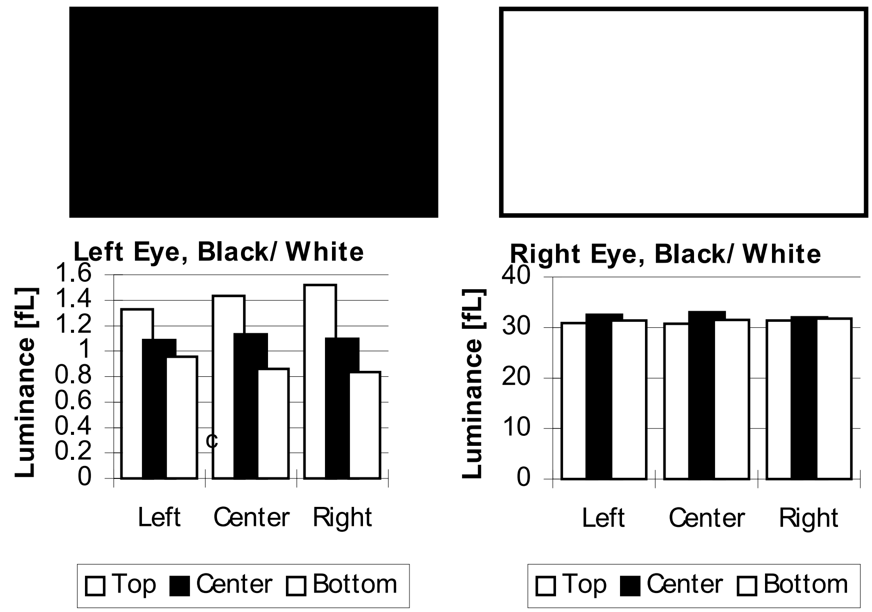


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

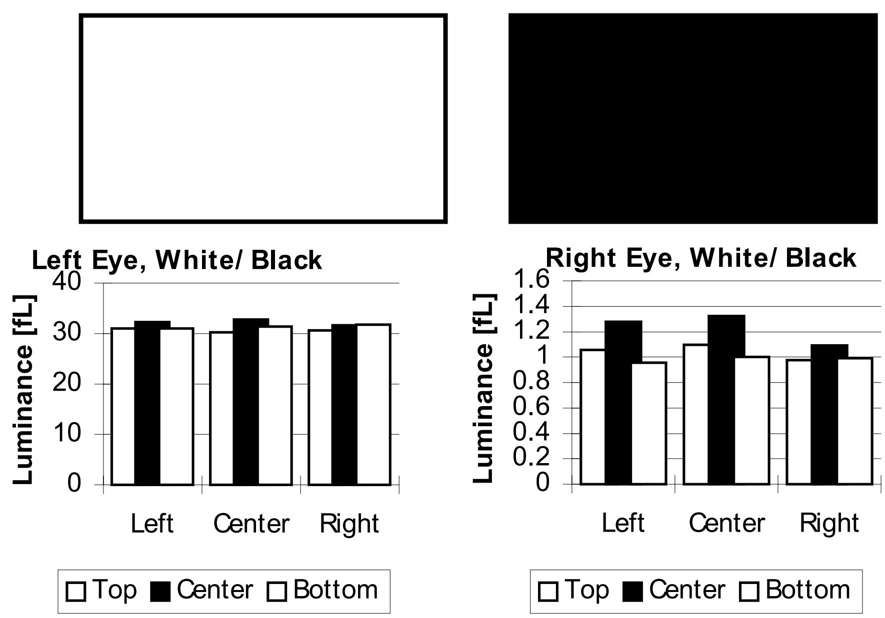


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

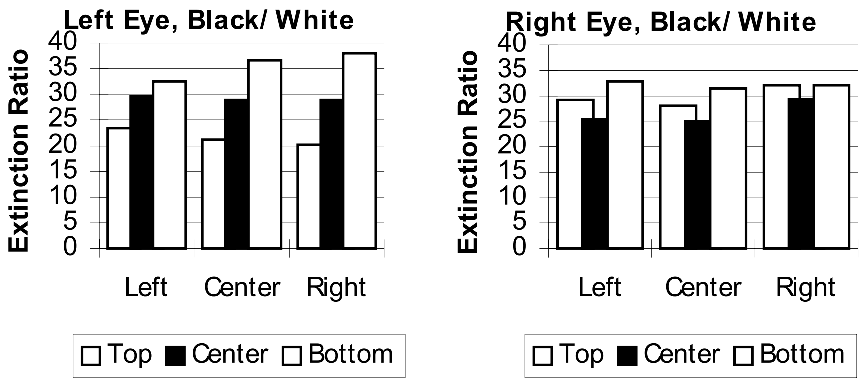


Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode.

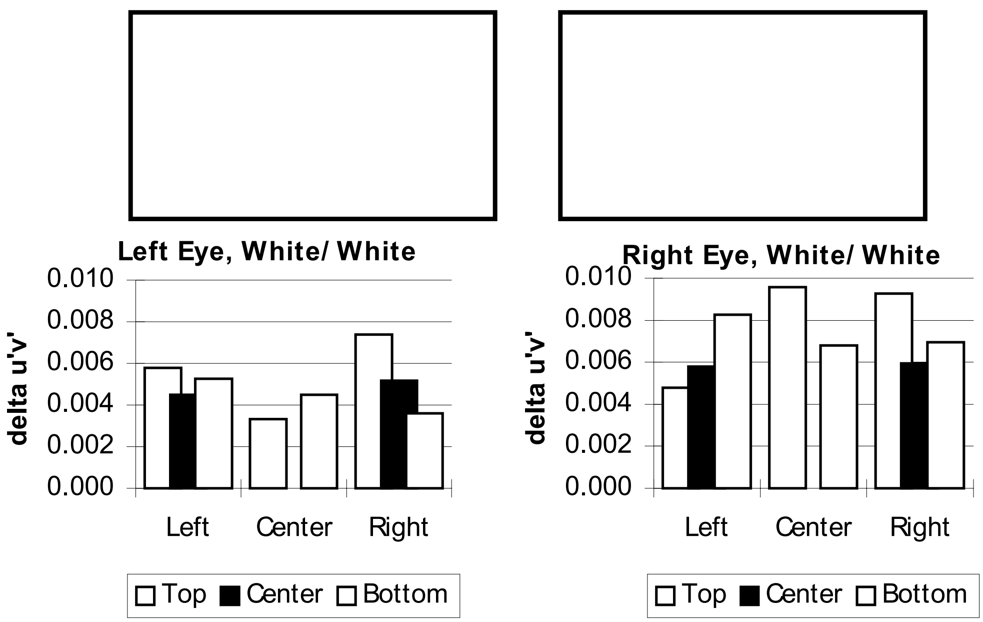


Fig.II.17-4 Spatial Uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 0.83% of full screen.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

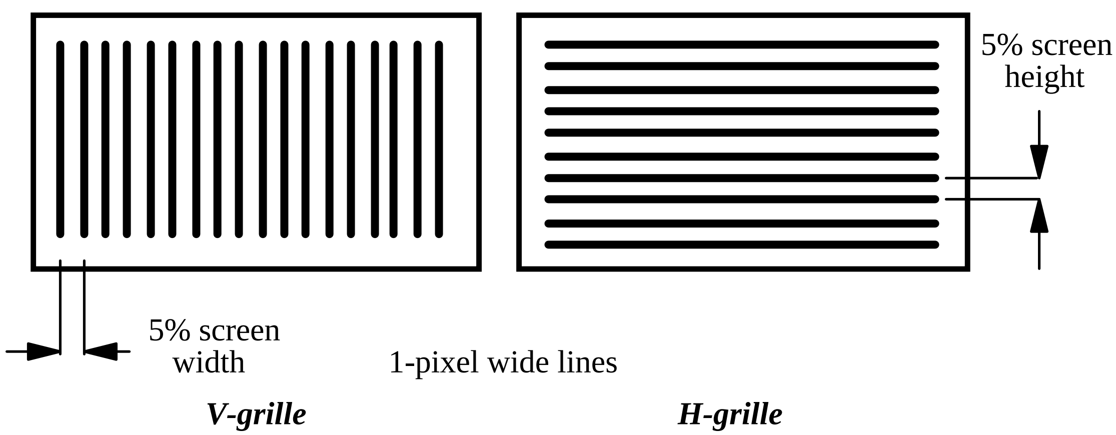


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

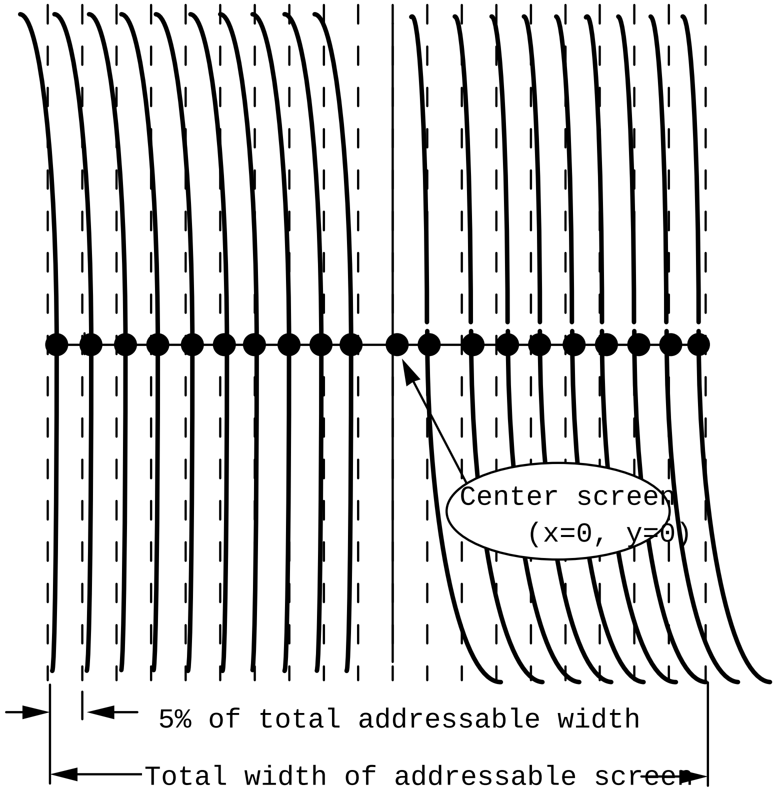


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

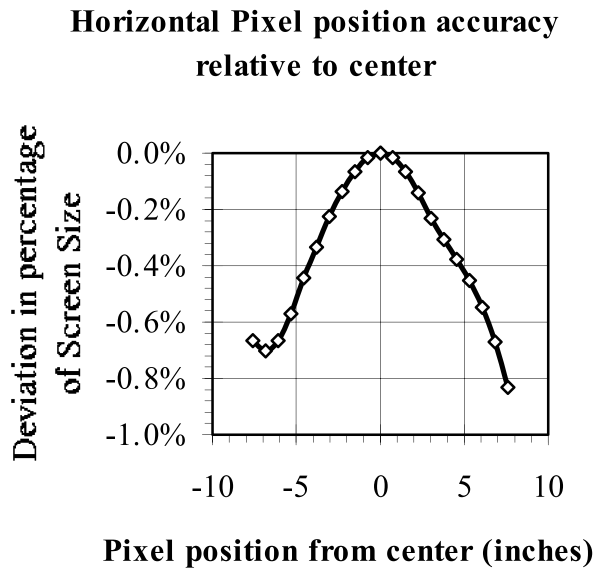
Data: Tabulate x,y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impacts the absolute position of each pixel on the screen and is, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figure II.18-3.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1600 x 1200	0.70%	0.83%	0.64%	0.46%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	**Right Side**	**Top**	**Bottom**
-7686	7459	5686	-5667
-6933	6725	5126	-5096
-6169	5985	4546	-4522
-5396	5241	3968	-3955
-4618	4494	3393	-3382
-3843	3746	2822	-2813
-3068	2999	2252	-2250
-2296	2254	1687	-1689
-1527	1507	1122	-1126
-761	756	561	-562
0	0	0	0



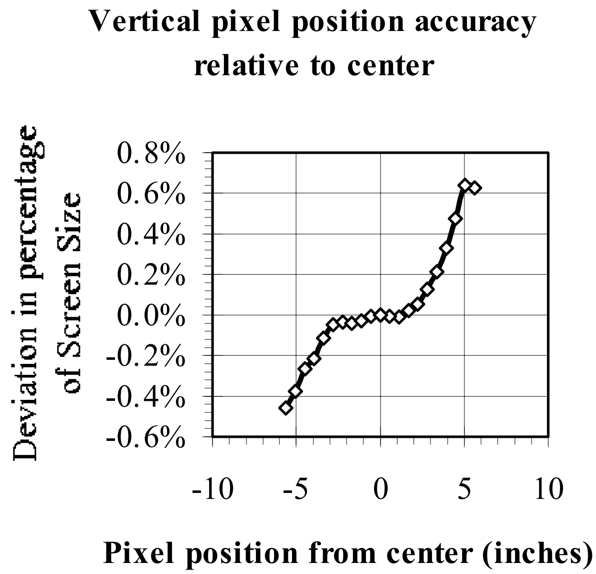


Fig. II.18-5 Horizontal and vertical linearity characteristics.

II.19. Jitter/Swim/Drift

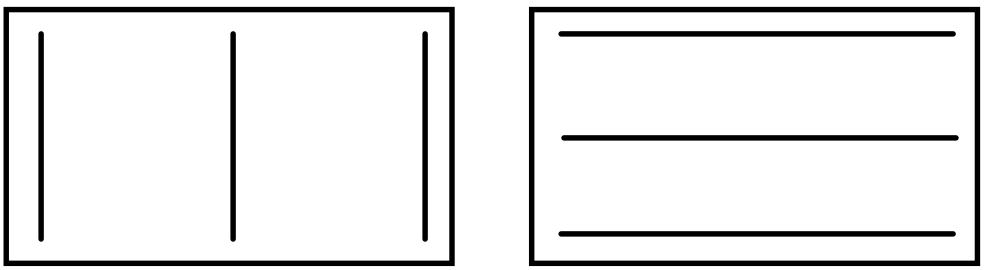
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift was 1.54 mils and 1.84 mils, respectively.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depend upon the amplitude and frequency of the motions which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion   H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-

1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

		H-lines	V-lines	
10D corner	Max Motions			
	Jitter	1.5	1.59	
	Swim	1.7	1.82	
	Drift	1.7	1.91	
Black Tape	Max Motions			
	Jitter	0.046	0.049	
	Swim	0.048	0.056	
	Drift	0.063	0.067	
Less Tape Motion				maximums
	Jitter	1.45	1.54	1.54
	Swim	1.65	1.76	1.76
	Drift	1.64	1.84	1.84

II.20 Warmup Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

A 56- minute warmup was necessary for luminance stability of Lmin = 0.129 fL +/- 10%.

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1280 x 1024 format in graphical form. The luminance remains very stable after 49 minutes.

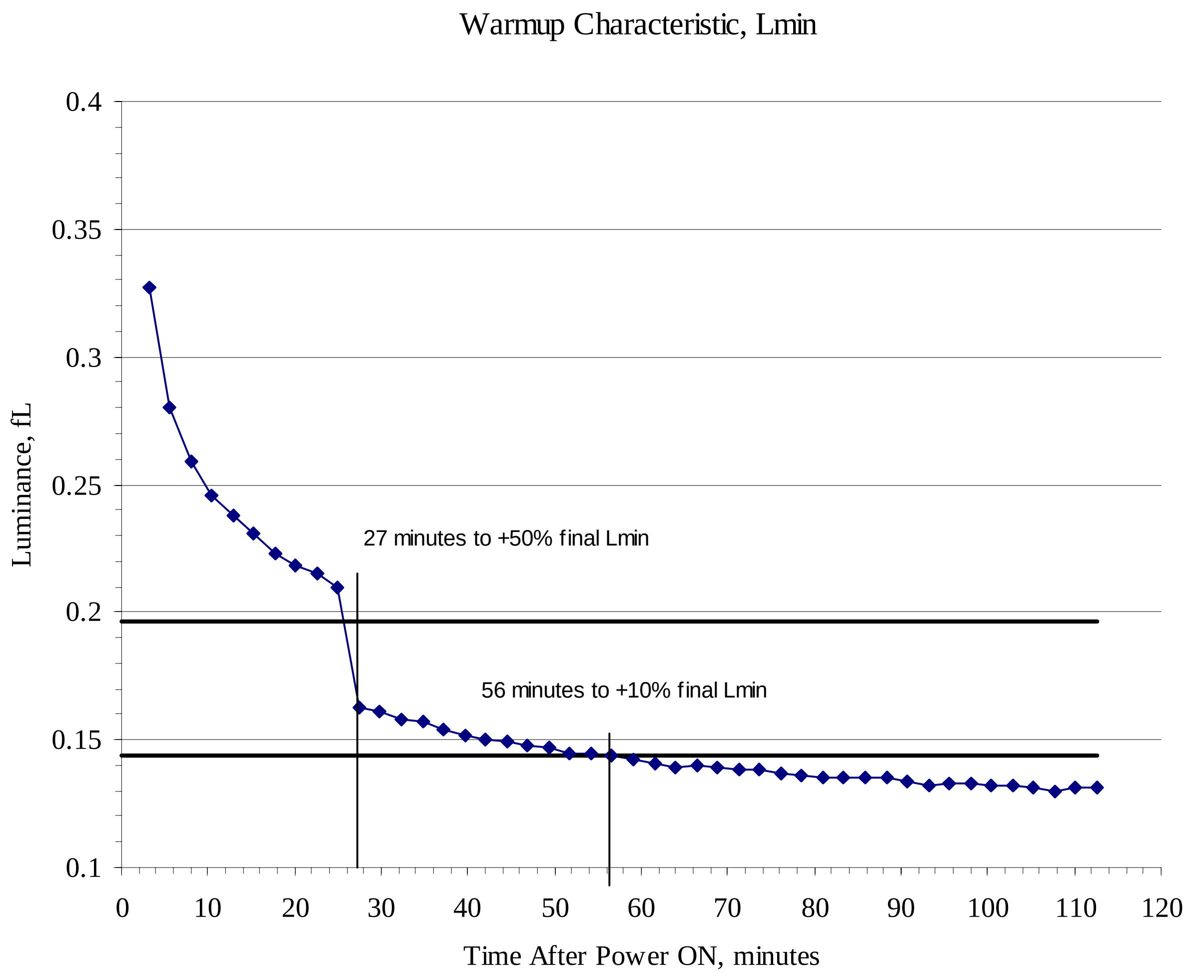


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).